태양에너지를 이용한 합성가스 제조기술 개요

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장소 : 한국광기술원

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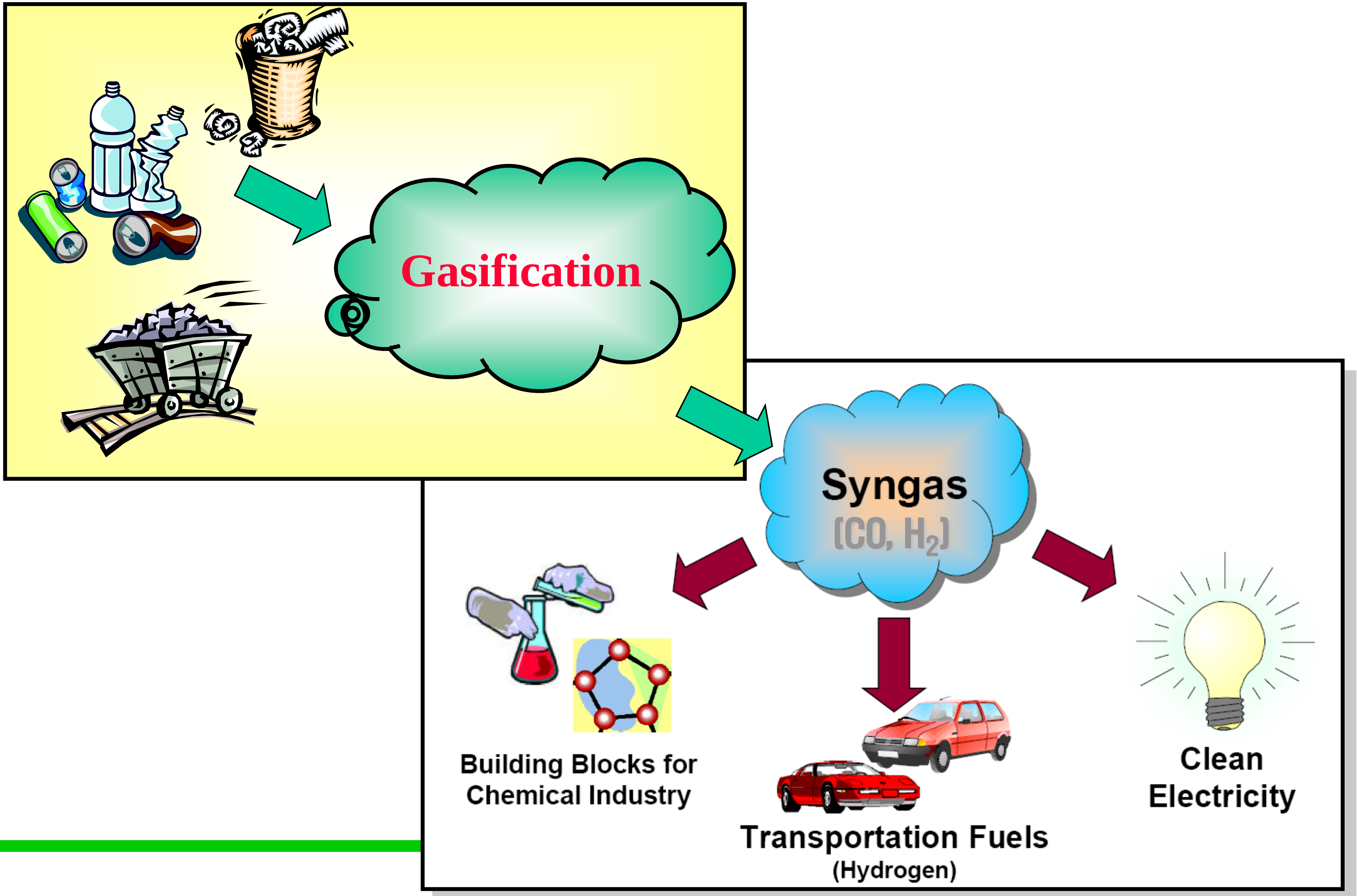
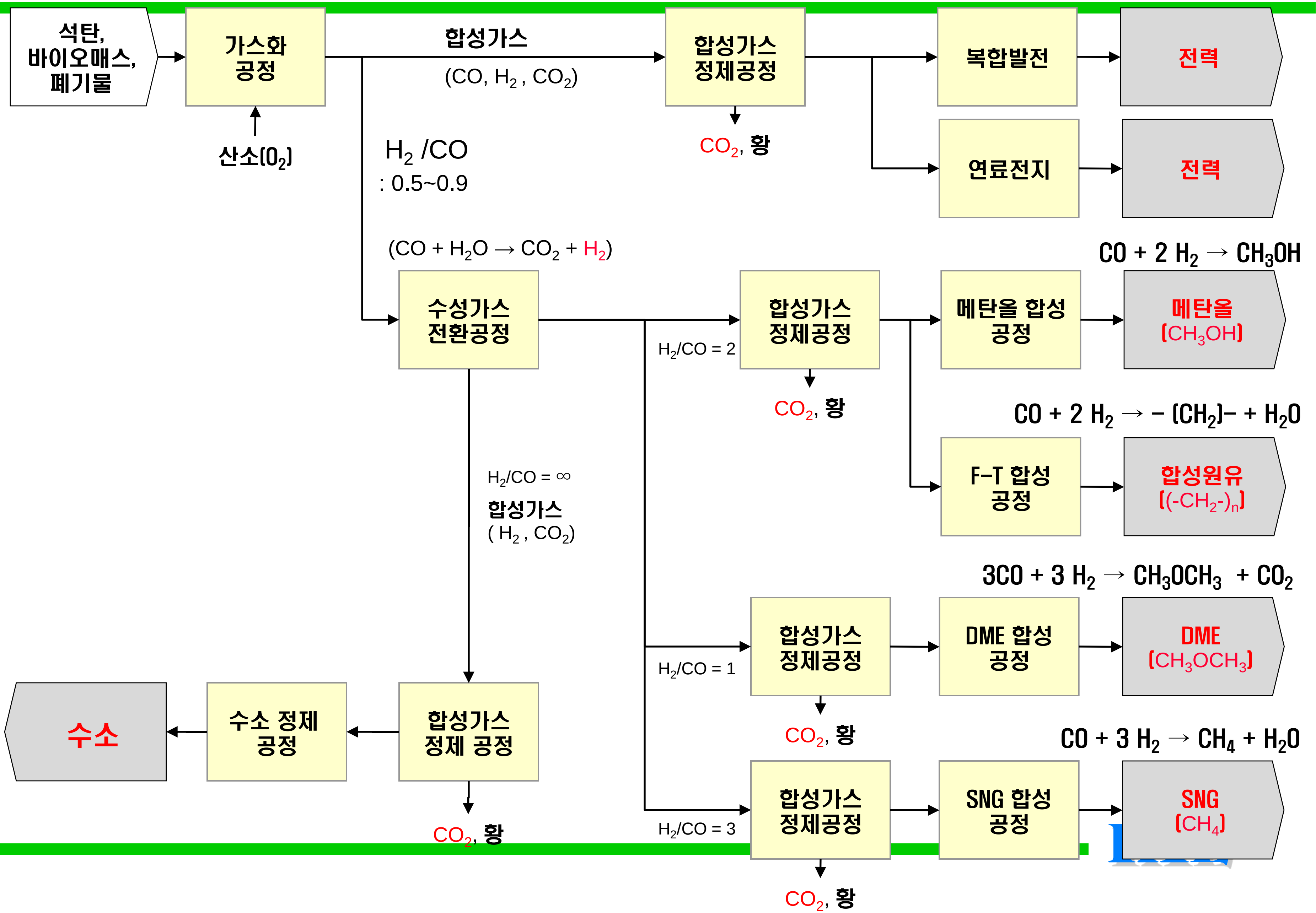
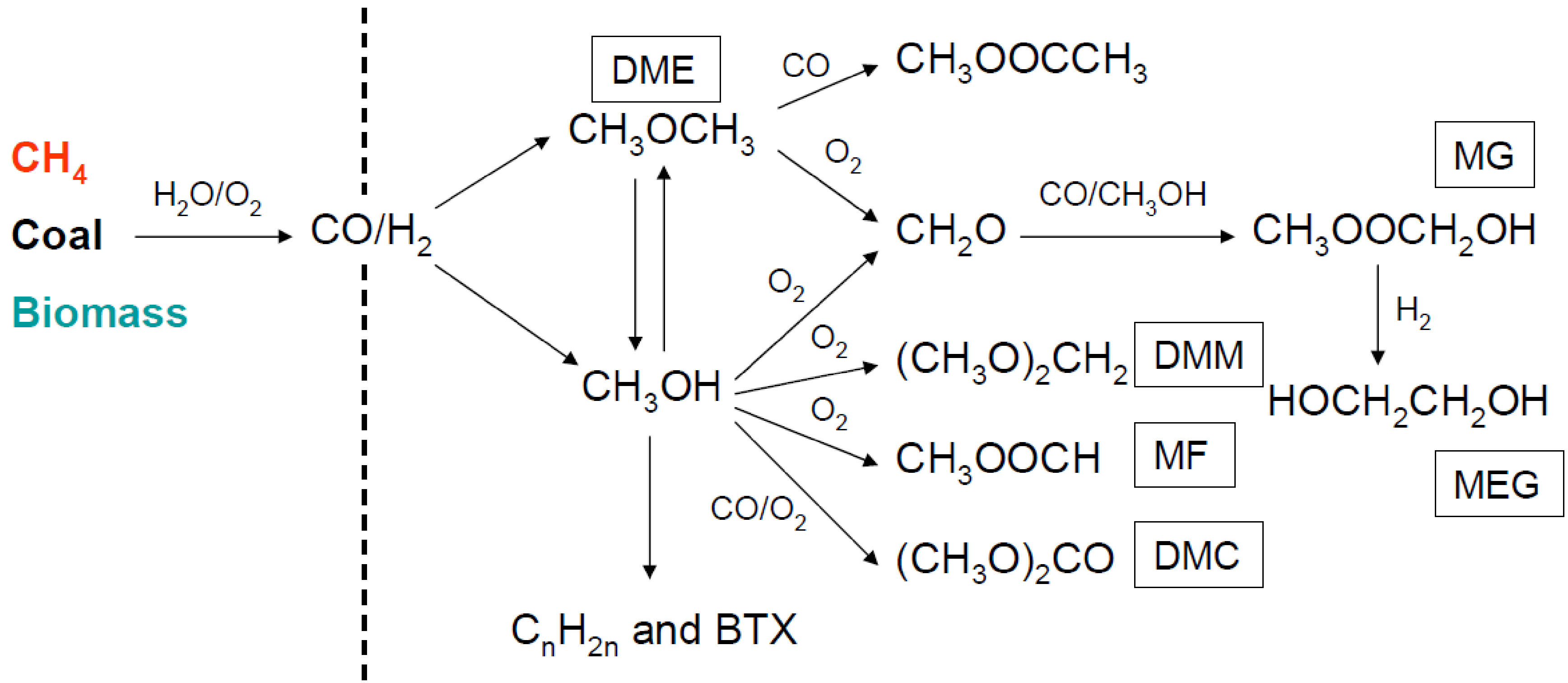
합성가스 (Synthesis Gas) ?



기존 가스화 기반의 연료 및 화학원료 활용 개념도

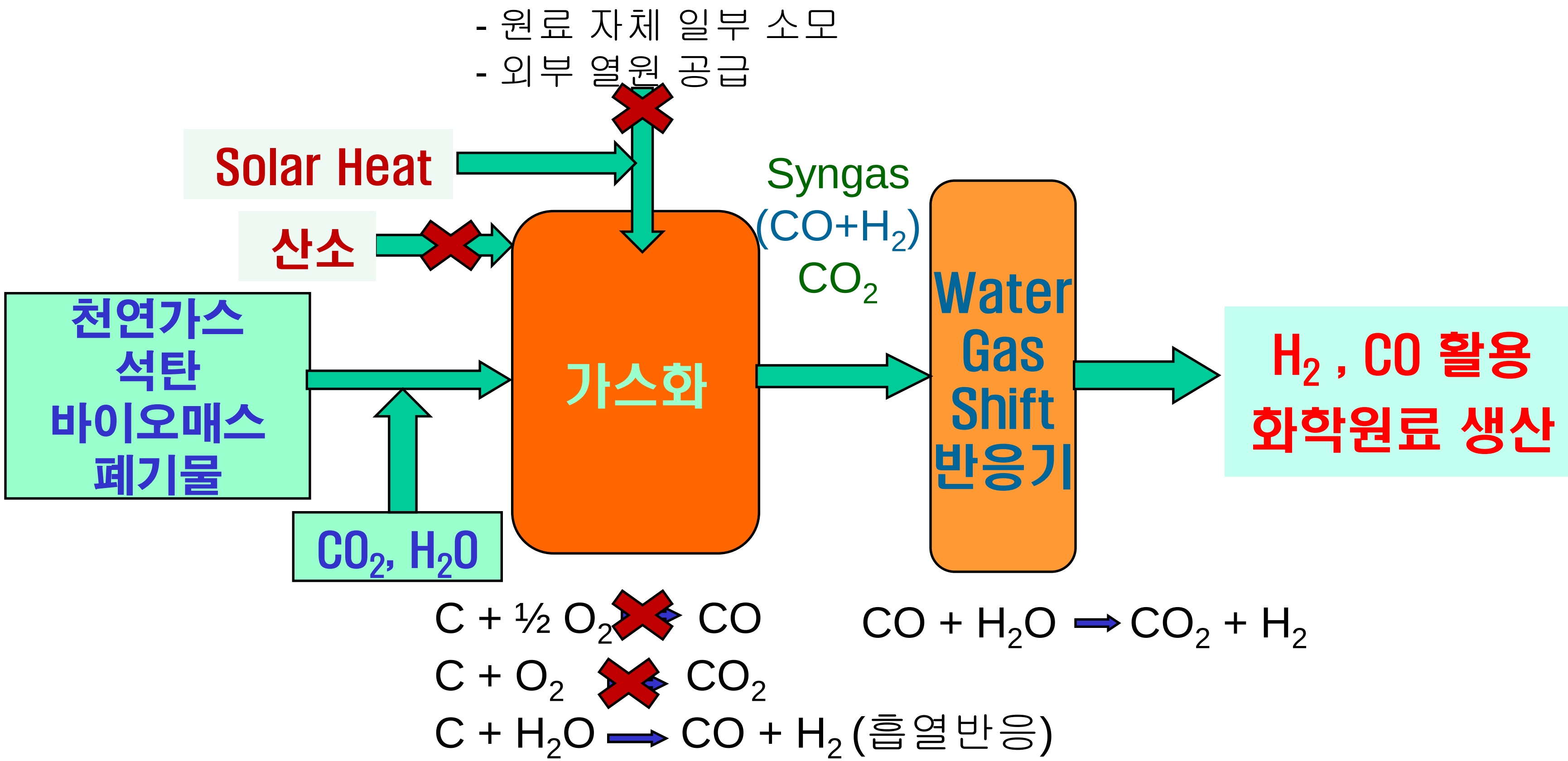


합성가스의 화학원료 이용 Route



DMM : Di-Methoxy Methane
MF : Methylformate
DMC : Di-Methyl Carbonate
MEG : Mono Ethylene Glycol

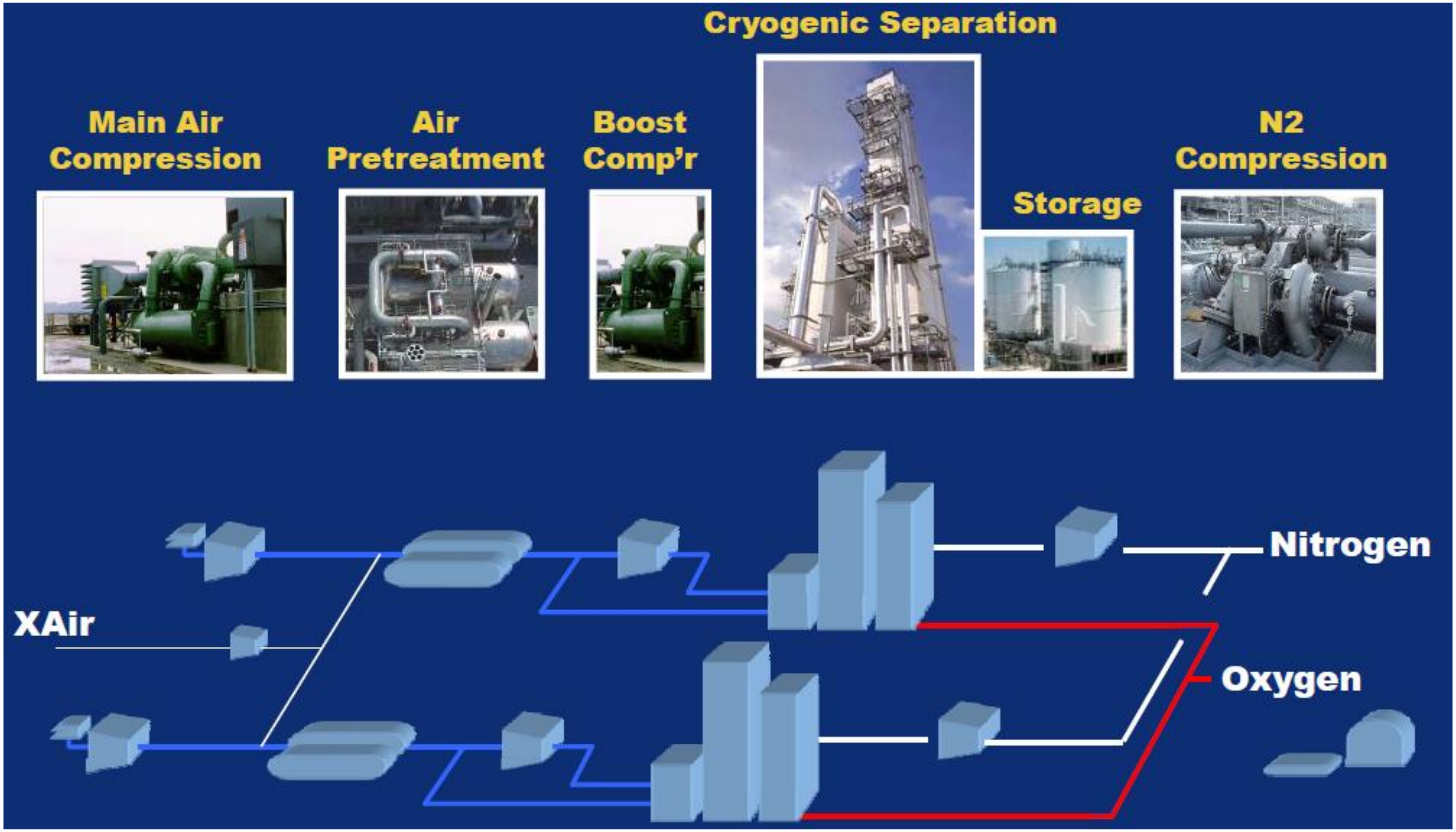
Solar(태양열) Syngas 변환의 개념



❑ 가스화 반응 진행에 요구되는 고온과 산소를 **Solar** 열원으로 대체하는 개념.

산소제조 설비 개선/대체 필요성

- 고가 설비, 대규모 전기 소모 설비
- IGCC 플랜트 경우, ASU 건설비가 전체건설비의 20% 차지. 전기 10-15% 소모



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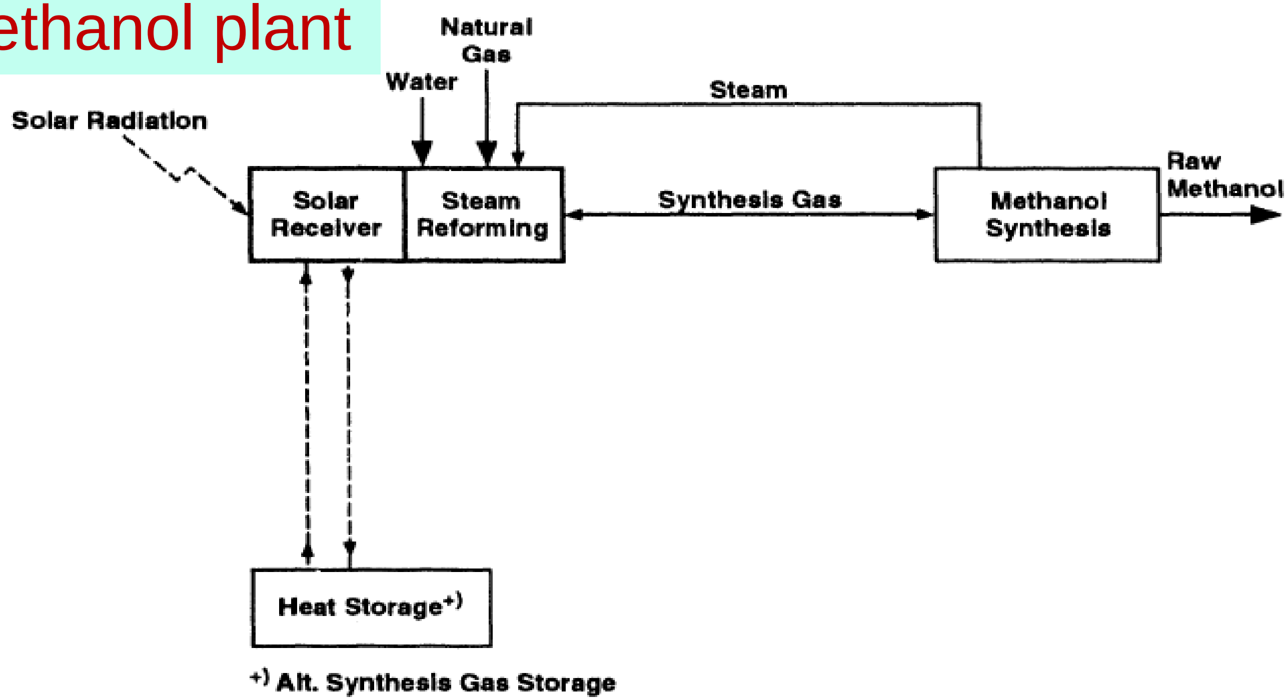
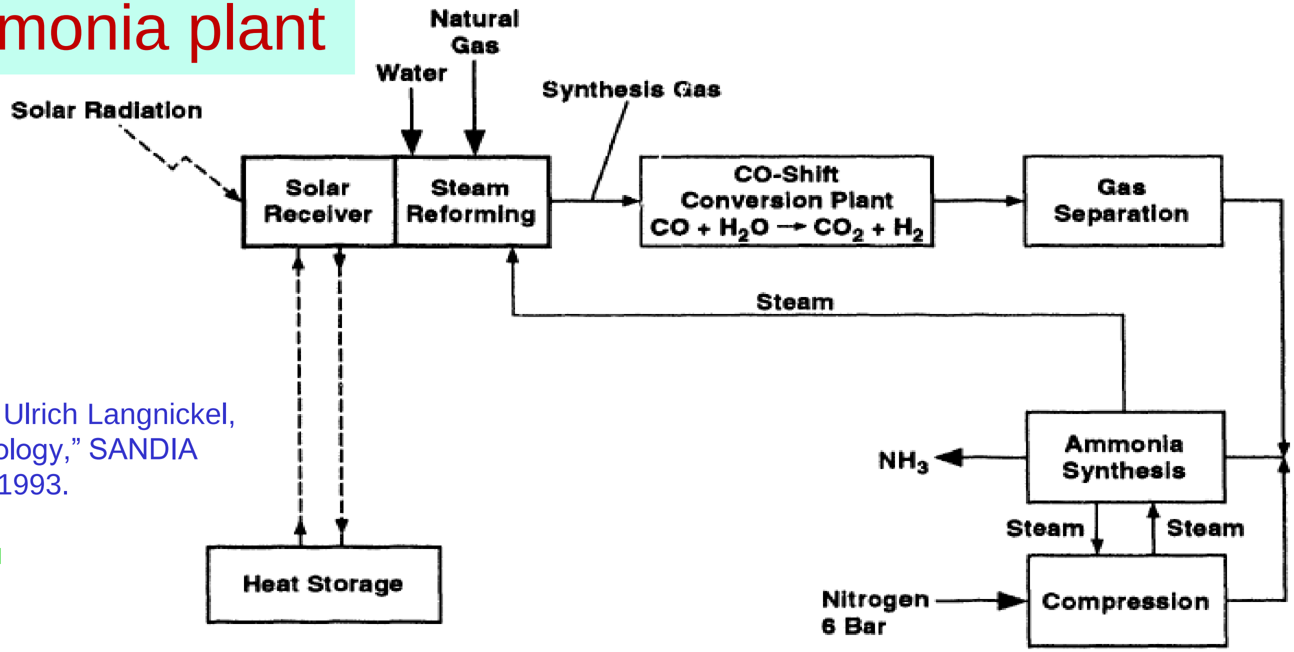
Source: Dave McCarthy, "ASU / IGCC Integration Strategies," Gasification Technologies Conference 2009, Colorado Springs, CO, 5 Oct. 2009.

Solar-assisted methanol plant



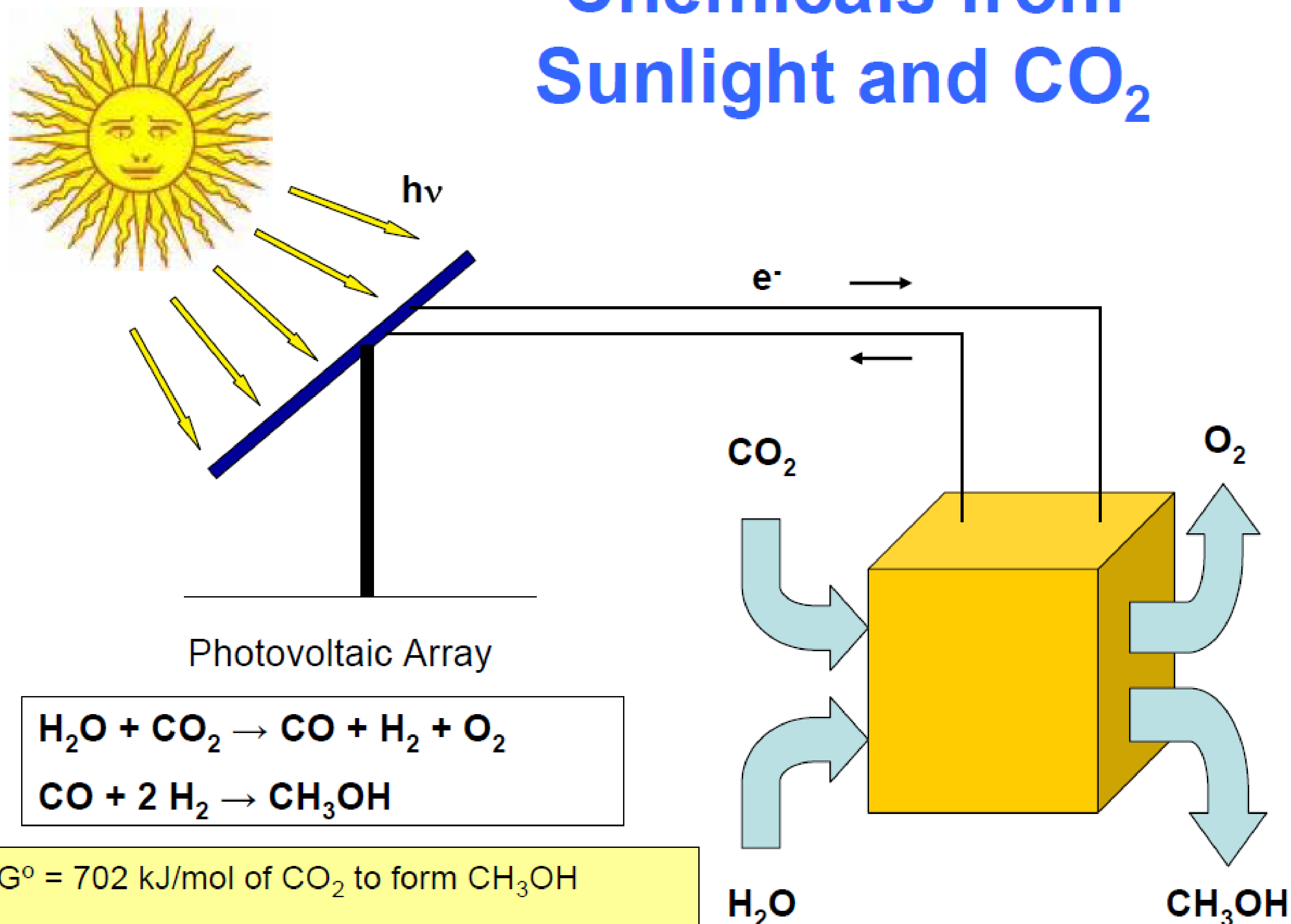
Solar-assisted ammonia plant



Source: Irving Spiewak, Craig E. Tyner, Ulrich Langnickel, "Applications of Solar Reforming Technology," SANDIA REPORT SAND93-1959 UC-237, Nov. 1993.

Solar(태양광) Syngas 변환

Chemicals from Sunlight and CO_2



$H_2O + CO_2 \rightarrow CO + H_2 + O_2$

$CO + 2\ H_2 \rightarrow CH_3OH$

ΔG^o = 702 kJ/mol of CO_2 to form CH_3OH

ΔG^o = 22 kJ/mol of CO_2 for separation from air

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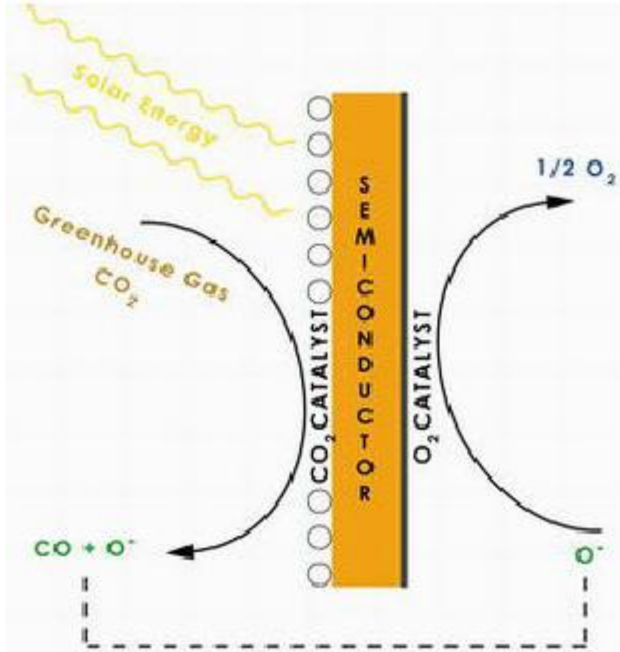
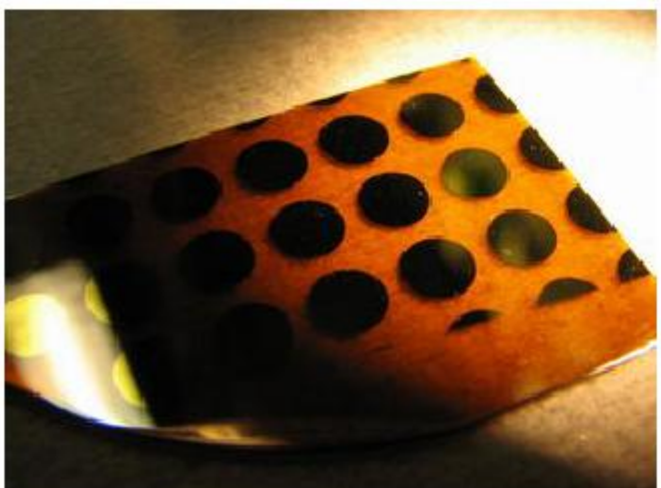
Source: Alexis T. Bell, "New Feed stocks for the Chemical Industry", University of California, Berkeley.

Solar CO_2-to-Fuel 개념



$CO_2 \Rightarrow CO + O_2$



CO2 splitting semiconductor/catalyst device under construction (gallium phosphide wafer with metal contacts) Credit: Aaron Sathrum, UCSD

Source: http://www.physorg.com/news96107693.html

Chemists at the University of California, San Diego have demonstrated the feasibility of exploiting sunlight to transform a greenhouse gas into a useful product.

Solar Steam Gasifier 개념 Example

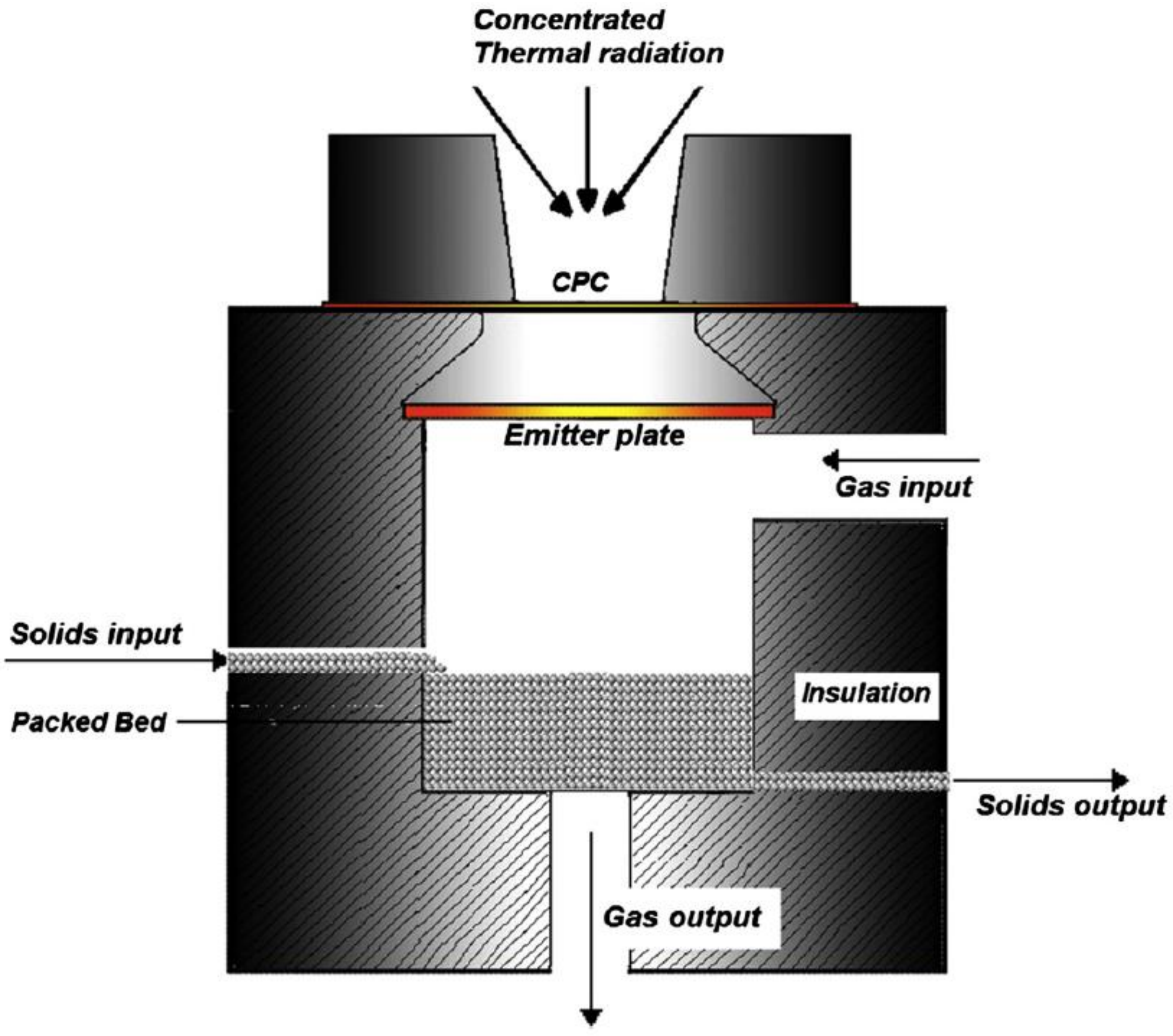


Fig. 1 – A downdraft gasifier with concentrated thermal radiation as source of energy.

Source: E.D. Gordillo, A. Belghit, "A downdraft high temperature steam-only solar gasifier of biomass char: A modeling study," Biomass & Bioenergy, 35, 2034-2043 (2011).

Solar Steam Gasifier 개념 Example

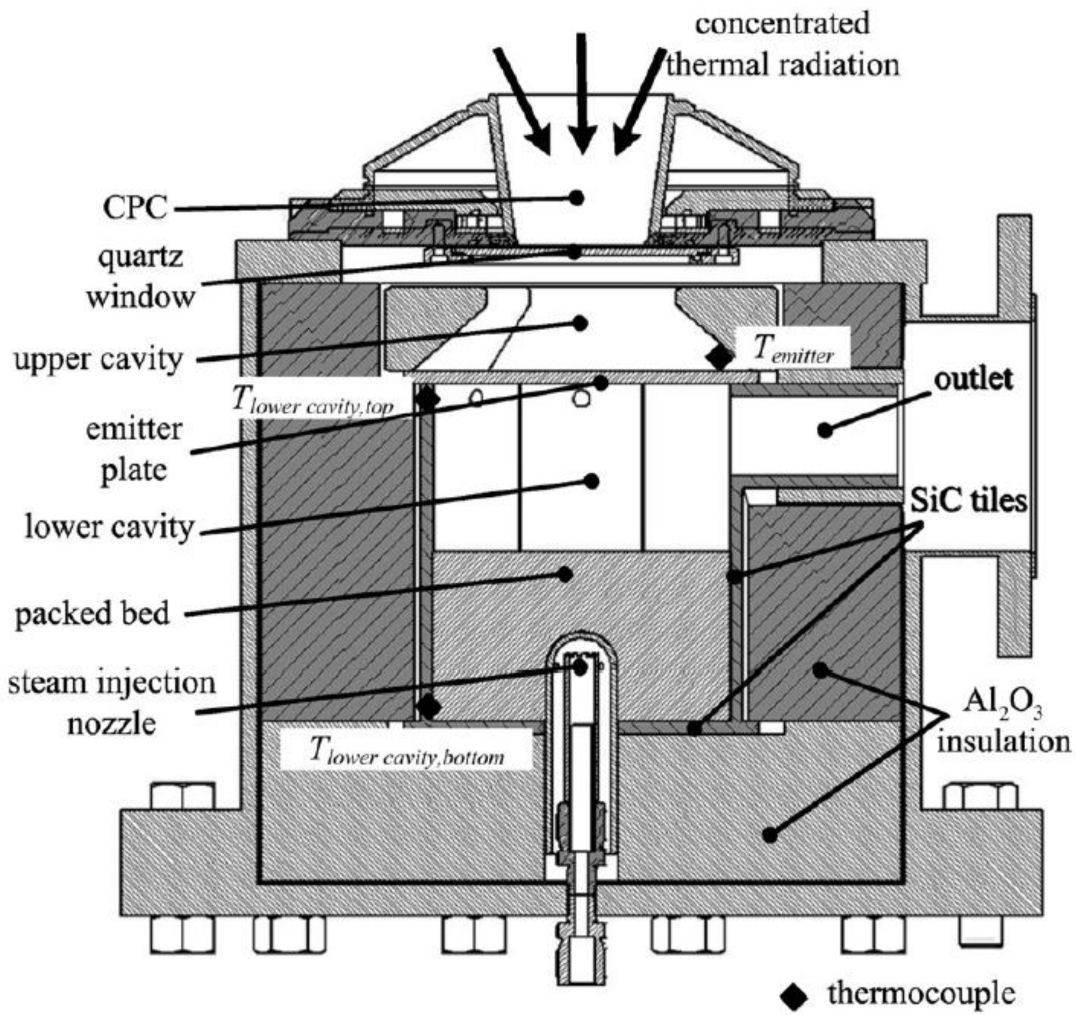


Fig. 1. Section view of the packed-bed solar reactor, featuring two cavities separated by an emitter plate, with the upper one serving as the radiative absorber and the lower one containing the reacting packed bed that shrinks as the reaction progresses.

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Source: Nicolas Piatkowski, Christian Wieckert, Aldo Steinfeld, "Experimental investigation of a packed-bed solar reactor for the steam-gasification of carbonaceous feedstocks," Fuel Processing Technology 90 (2009) 360–366.

Solar Steam Gasifier 개념 Example

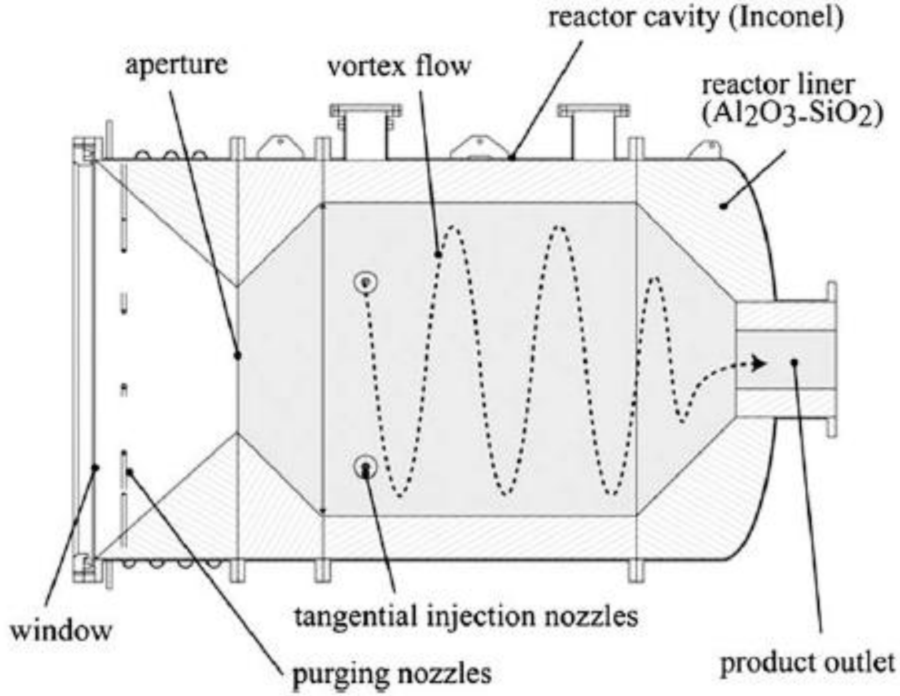
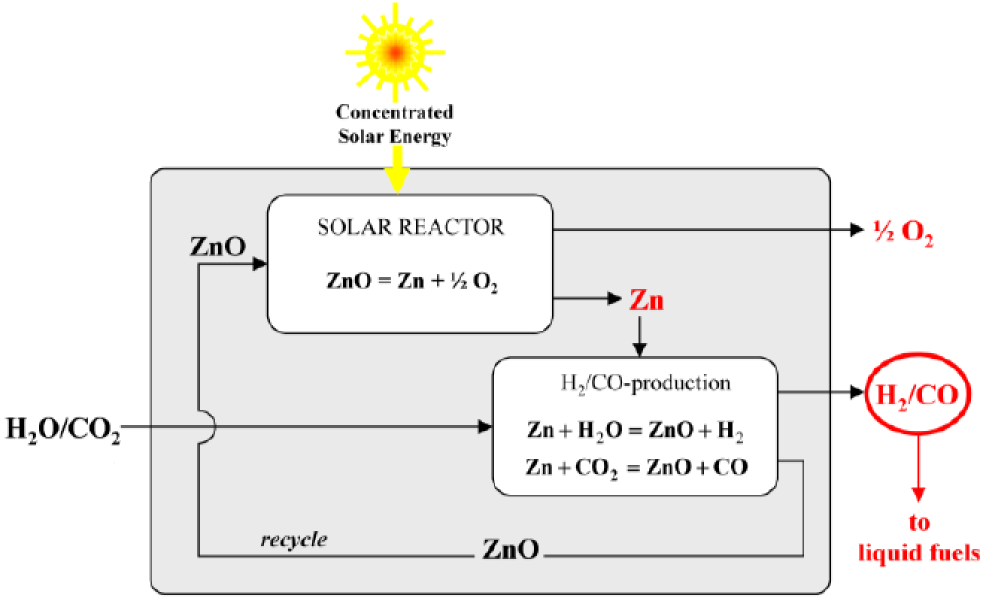


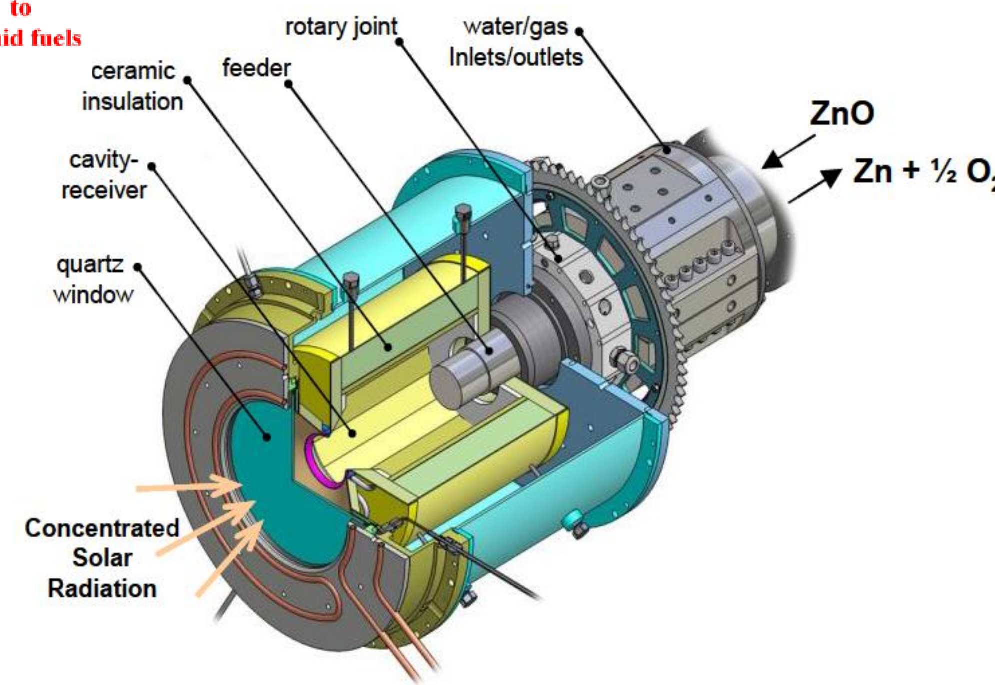
Fig. 1 – Scheme of the solar chemical reactor configuration for the steam-gasification of coke, featuring a continuous gas-particle vortex flow confined to a cavity-receiver and directly exposed to concentrated solar radiation.

Source: A. Z'Graggena, A. Steinfelda, "Hydrogen production by steam-gasification of carbonaceous materials using concentrated solar energy – V. Reactor modeling, optimization, and scale-up," Int. J. of Hydrogen Energy, 33, 5484-5492 (2008).

Chemical Looping 반응기 개념 적용 Case



. Schematic of the solar rotary reactor configuration



Source: Peter G. Loutzenhiser, Anton Meier and Aldo Steinfeld, "Review of the Two-Step H2O/CO2-Splitting Solar Thermochemical Cycle Based on Zn/ZnO Redox Reactions," Materials 2010, 3, 4922-4938.

혁신 개념의 Solar Gasoline

(2011. 5월호)

1) Fusion-Triggered Fission
2) Solar Gasoline
3) Quantum Photovoltaics
4) Heat Engines
5) Shock-Wave Auto Engine
6) Magnetic Air Conditioners
7) Clean(er) Coal – Ionic Liquids

LIQUID FUELS

Solar Gasoline

Concentrated sunlight and carbon dioxide propel vehicles

LIKELIHOOD

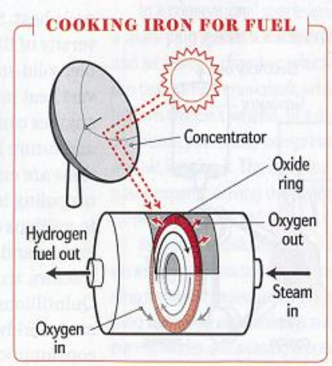
POTENTIAL IMPACT

THE SUN BATHES THE EARTH IN MORE ENERGY in an hour than civilization uses in a year. If scientists could convert even a fraction of that surplus into a liquid fuel, our addiction to fossil fuels for transportation, and the problems they cause, could end. "Chemical fuels would be the game changer if you could directly make them efficiently and cheaply from sunlight," notes Nathan Lewis, director of the Joint Center for Artificial Photosynthesis at the California Institute of Technology.

One intriguing effort at Sandia National Laboratories employs a six-meter-wide dish of mirrors in the New Mexico desert. It concentrates the sun's rays on a half-meter-long cylindrical machine shaped like a beer keg that is mounted in front of the dish. The mirrors focus sunlight through a window in the machine's wall on a dozen concentric rings that rotate once a minute. Teeth of iron oxide (rust) or cerium oxide rim the rings and rotate into the beam, heating to 1,500 degrees Celsius. That heat drives the oxygen out of the rust. As the teeth rotate back into the cooler, dark side of the reactor, they suck oxygen back out of steam or out of carbon dioxide that has been introduced into the chamber, leaving behind energy-rich hydrogen or carbon monoxide.

The resulting mixture of hydrogen and carbon monoxide is called synthesis gas, or syngas—the basic molecular building block for fossil fuels, chemicals, even plastics. The process could also absorb as much CO_2 as is emitted when the fuel is burned. Such a system of solar fuels "is like killing four birds with one stone," says Arun Majumdar, director of the Advanced Research Projects Agency-Energy: clean fuel supply, greater energy security, carbon dioxide reduction and less climate change.

Researchers elsewhere, including at the Swiss Federal Institute of Technology in Zurich and the University of Minnesota, are developing syngas-producing machinery. And some start-up companies are pursuing other paths. Sun Catalytix in Cambridge, Mass., dips a cheap catalyst into water and,



using electricity from a solar panel, creates hydrogen and oxygen. Liquid Light in Monmouth Junction, N.J., bubbles CO_2 into an electrochemical cell that builds it into methanol. And Lewis himself is building artificial leaves from semiconducting nanowires that absorb sunlight to split water into hydrogen and oxygen.

Of course, overcoming practical problems is the main hurdle. At Sandia, the teeth keep cracking, impeding the reaction. "You're cycling back and forth from 1,500 degrees to 900 degrees; that's a lot to ask of a material," notes chemist Gary Dirks, director of LightWorks at Arizona State University, who is not involved with the work. The next step is to make the rust structure more robust at the nanoscale or to find even better tooth materials. The high cost of the mirrors would also have to drop. Sandia's researchers suggest their syngas engine can make fuel for $10 per gallon ($2.65 a liter). "We haven't proved to ourselves that we can't do it," says chemical engineer and co-inventor James E. Miller, "but we're a long way from doing it." —*David Biello*

THE SUN BATHES THE EARTH IN MORE ENERGY in an hour than civilization uses in a year. If scientists could convert even a fraction of that surplus into a liquid fuel, our addiction to fossil fuels for transportation, and the problems they cause, could end. "Chemical fuels would be the game changer if you could directly make them efficiently and cheaply from sunlight," notes Nathan Lewis, director of the Joint Center for Artificial Photosynthesis at the California Institute of Technology.

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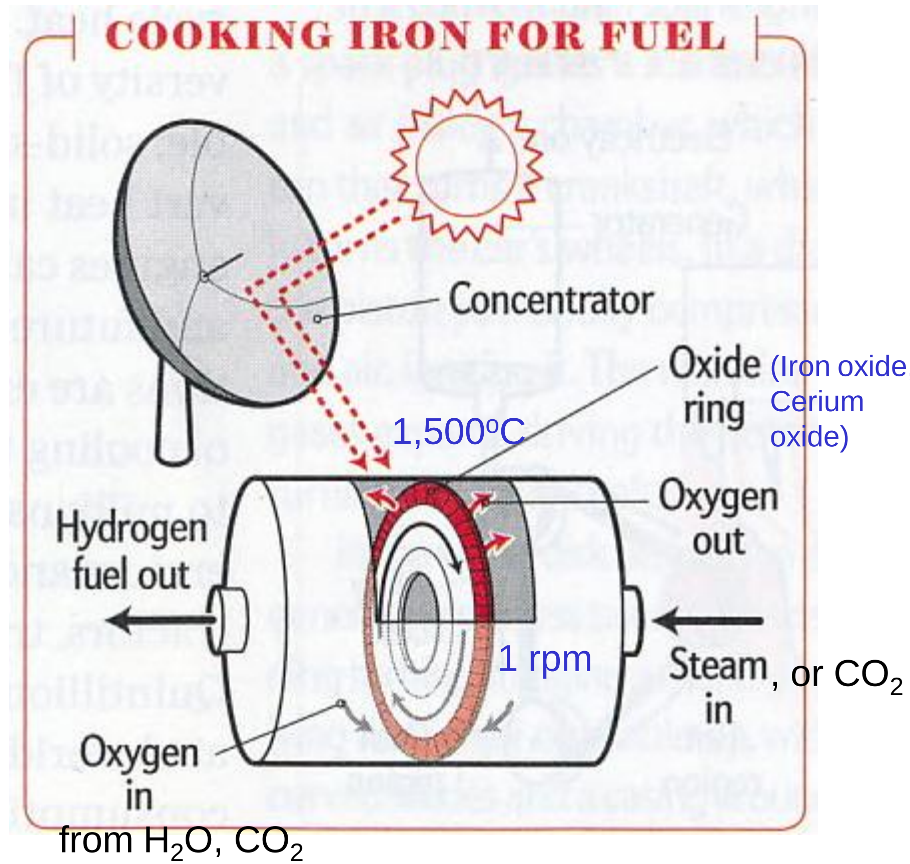
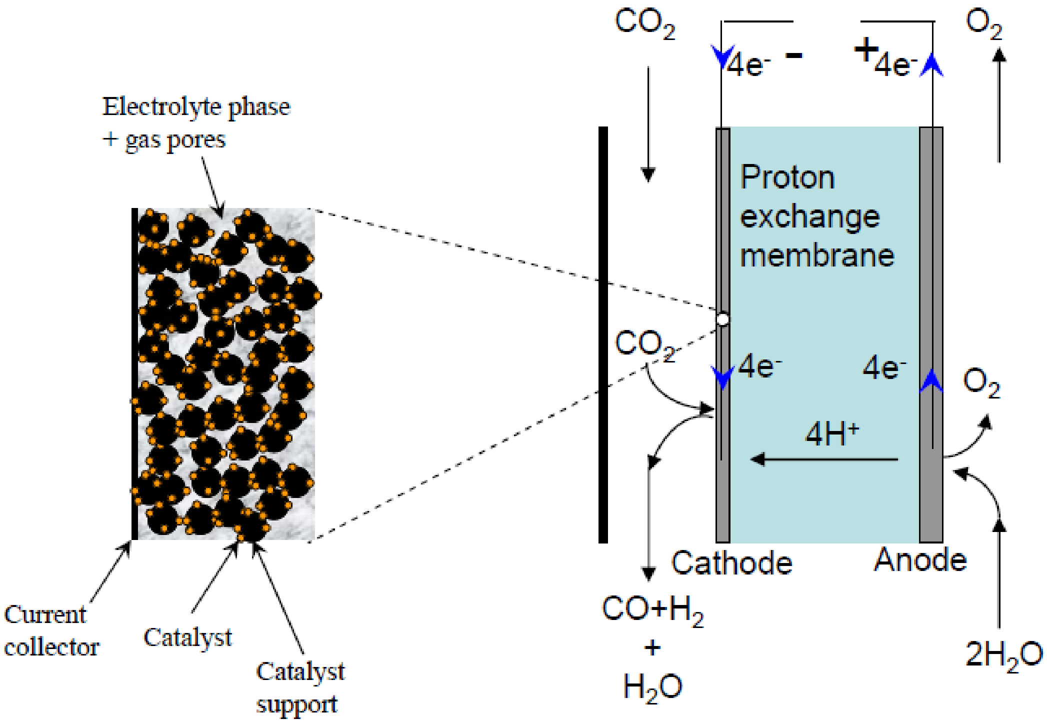
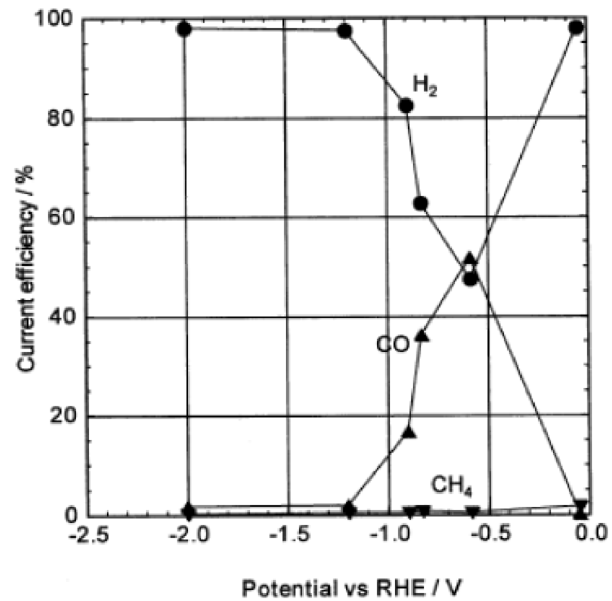
(Sandia National Lab. 개념)



Electrochemical Reduction of CO_2 to CO/H_2 and O_2





T. V. Magadesieva et al., *J. Electrochem. Soc.*, **149**, D89 (2002)

Anode: 2 $H_2O \rightarrow 4\ H^+ + 4\ e^- + O_2$

Cathode: $CO_2 + 4\ H^+ + 4\ e^- \rightarrow H_2 + CO + H_2O$

- Regulation of the cell voltage allows the H_2/CO ratio to be set

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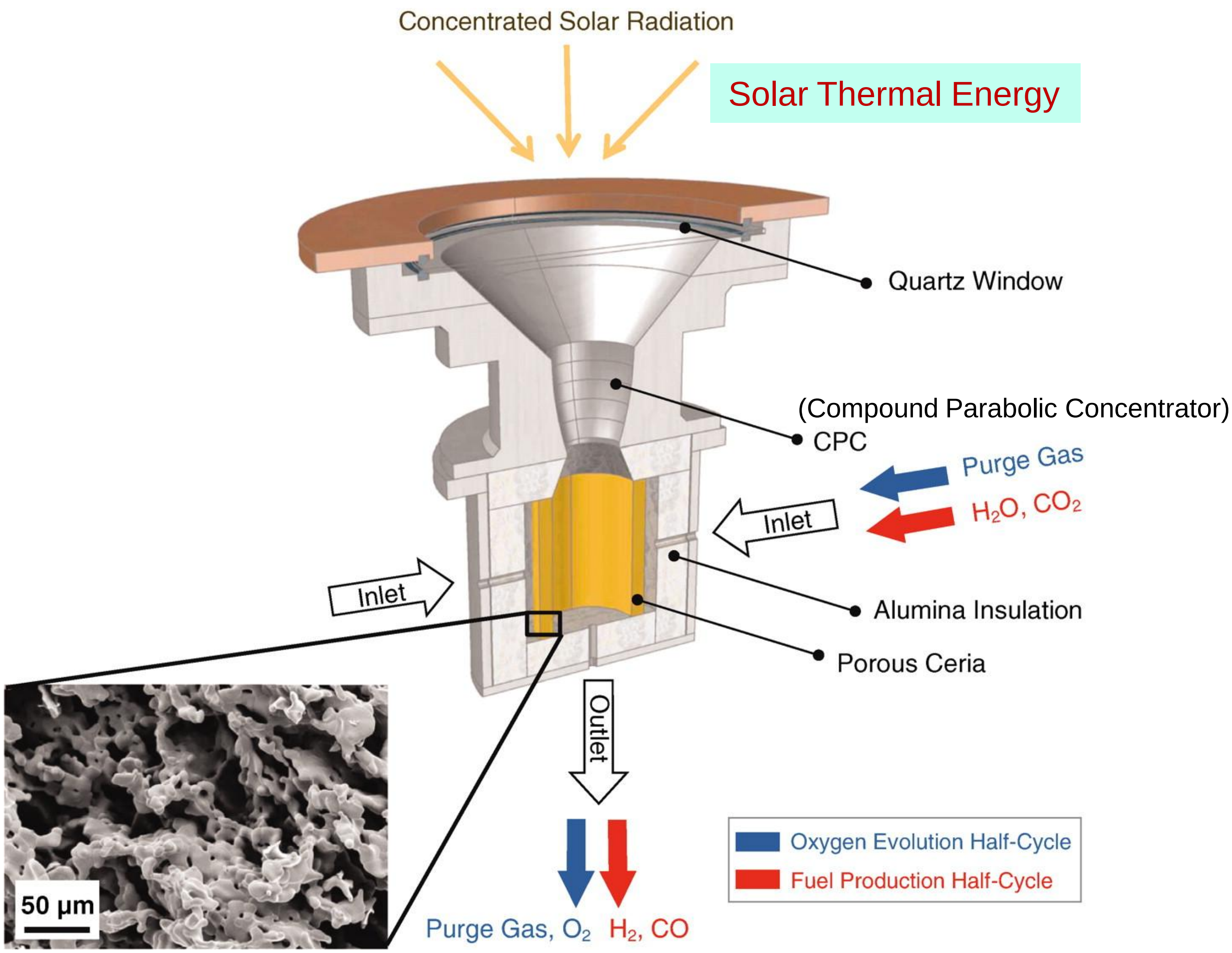
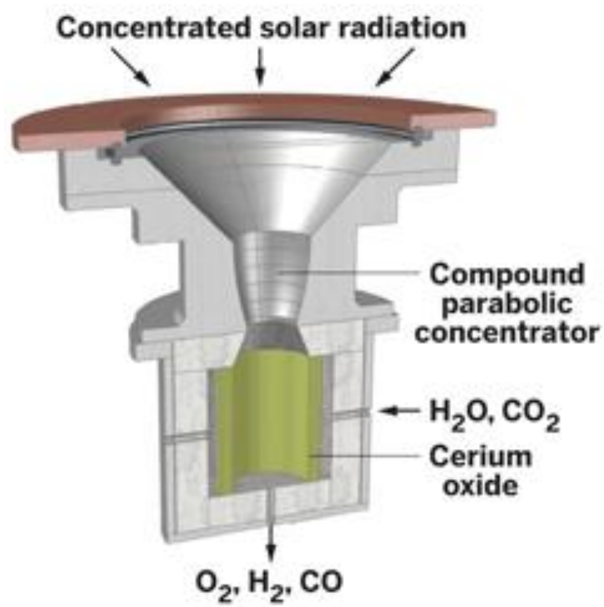
Source: Alexis T. Bell, “New Feed stocks for the Chemical Industry”, University of California, Berkeley.

Fig. 1 Schematic of the solar reactor for the two-step, solar-driven thermochemical production of fuels.



W C Chueh et al. Science 2010;330:1797-1801



The reactor's solar-to-syngas energy conversion efficiency, experimentally measured with a 2-kW prototype, is 0.7 to 0.8%, which Steinfeld says is significantly higher than those of current photocatalytic methods for CO_2 dissociation.
A thermodynamic analysis indicates that efficiencies of 16% or more are achievable with the new reactor.

The reactor was designed by solar technology specialist Aldo Steinfeld of ETH, the Swiss Federal Institute of Technology, Zurich; materials scientist Sossina M. Haile of California Institute of Technology; and coworkers (*Science*, DOI: 10.1126/science.1197834). It uses concentrated solar energy to thermochemically dissociate CO_2 and H_2O via cerium oxide redox reactions to produce CO and H_2, respectively, with O_2 as a by-product. CO and H_2 form syngas, which can be processed to generate methanol, gasoline, and other liquid fuels.

Source: Chueh WC, Falter C, Abbott M, Scipio D, Furler P, Haile SM, Steinfeld A. High-Flux Solar-Driven Thermochemical Dissociation of CO2 and H2O using Nonstoichiometric Ceria. Science, 24 December 2010: Vol. 330 no. 6012, pp. 1797-1801.

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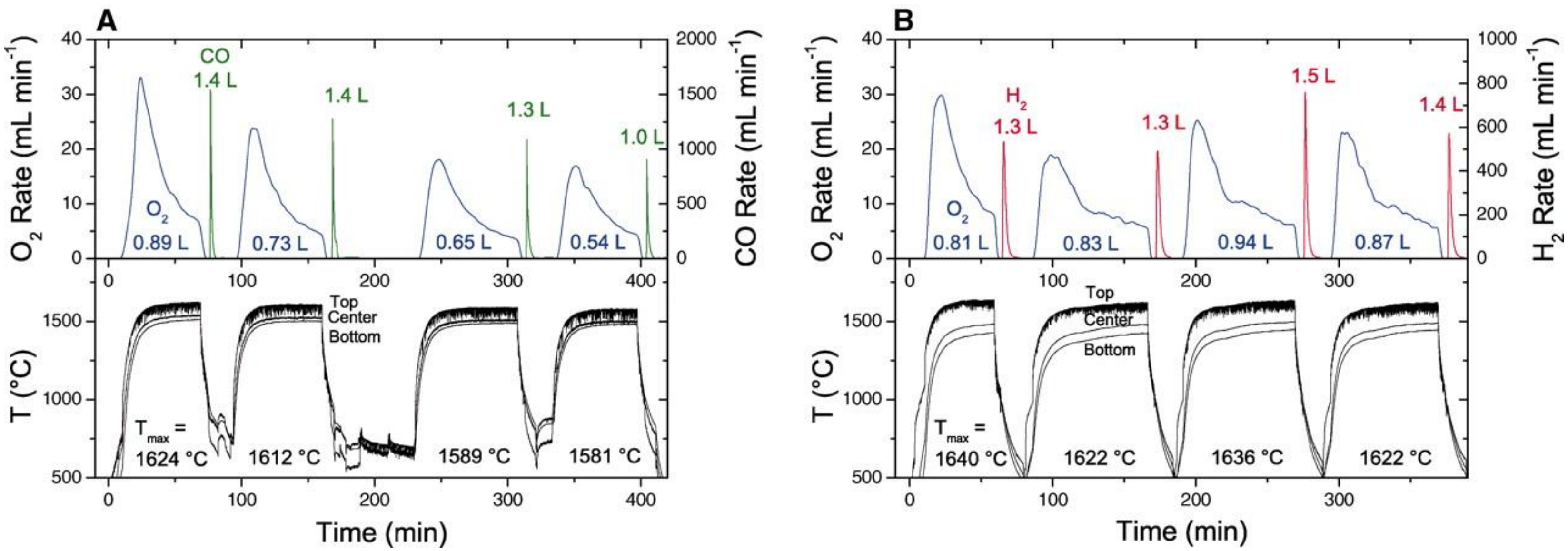
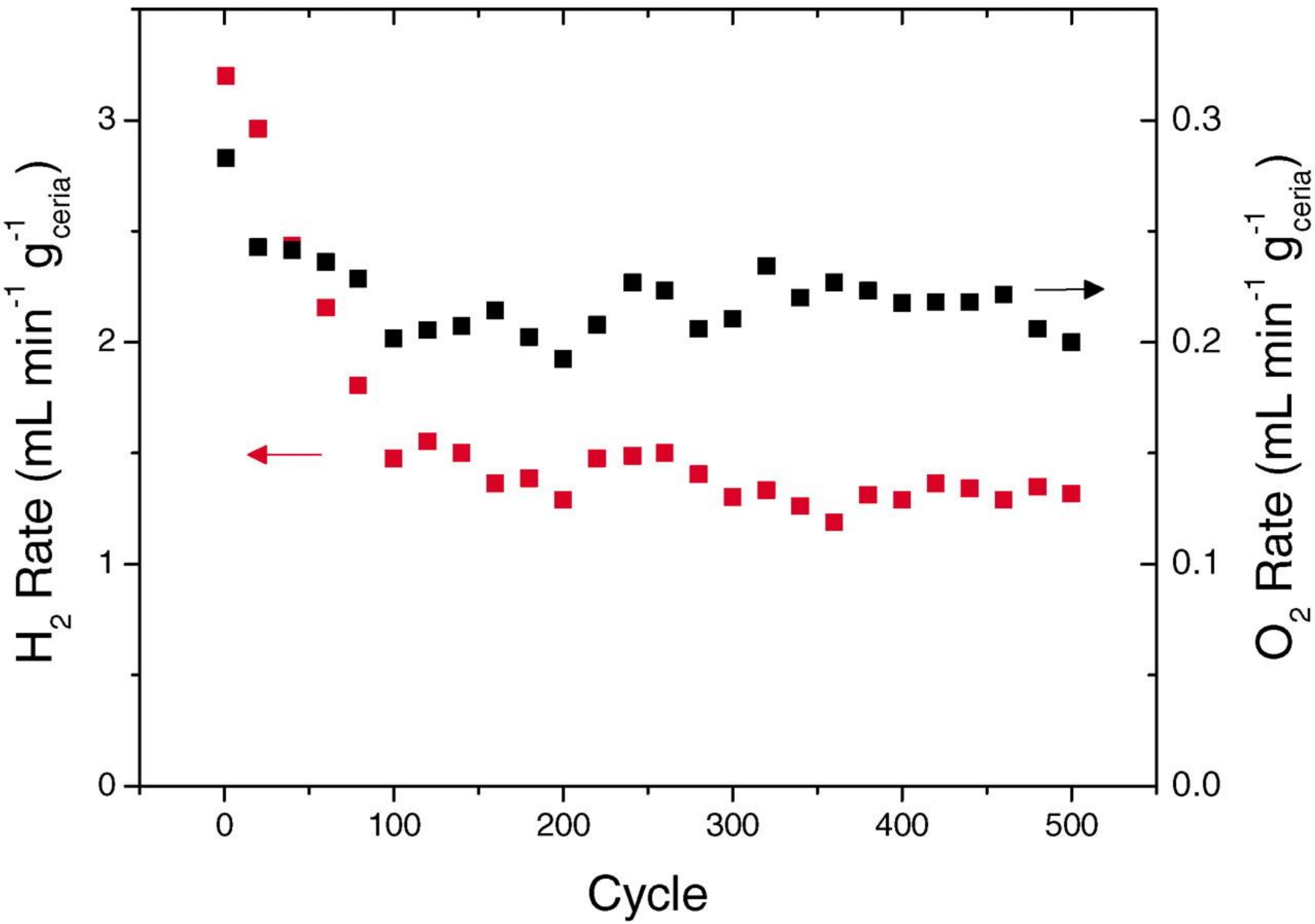
Fig. 2 Thermochemical cycling of ceria (325 g) using the solar reactor with (A) CO2 and (B) H2O as oxidant.



W C Chueh et al. Science 2010;330:1797-1801

Fig. 4 O2 (black) and H2 (red) evolution rates for 500 water-splitting cycles.



W C Chueh et al. Science 2010;330:1797-1801

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요 약

- The ultimate source of H_2 for the Chemical Process Industry is H_2O
- The ultimate source of C may be atmospheric CO_2
- 태양에너지 집광, 촉매, 재료 분야에서 혁신기술 개발이 필요
- 2030년 이후 태양에너지가 재생가능에너지의 가장 핵심이고 대량 보급이 유력
- 장기간 집중된 노력과 학제간 융합이 필요한 대상 기술분야
- 대학과 국가 출연기관에서 혁신적 기술개발 노력이 필요한 분야
- 혁신적 기술은 아직 없지만, 기타 기반 기술은 국내에 충분히 보유

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Source: Alexis T. Bell, “New Feed stocks for the Chemical Industry”, University of California, Berkeley.